APPENDIX C

VEGETATION AND SOILS
MAPPING AND ANALYSIS

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LAKEBELT ECOLOGICAL STUDIES, DADE COUNTY

Final Report

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September 3, 1996

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Executive Summary

In order to evaluate a proposed limestone mining plan for the Lakebelt Region in northwest Dade County, Florida, the Department of Environmental Resources Management of Dade County (DERM), with funding assistance from the South Florida Water Management District, the Army Corps of Engineers and the South Florida Rockmining Coalition, proposed to assess the existing function and quality of freshwater wetlands in that region. Among the components of that assessment were the mapping and analysis of vegetation and soils, the analysis of existing and historical distribution of *Melaleuca quinquenervia*, and an analysis of factors which might be influencing the distribution of vegetation in the study area, including topography, soil type and hydrology. Other researchers collected data on wildlife and lake and littoral communities.

Cover types were defined by an interagency task force. They were digitized from aerial photographs and then ground-truthed. A soil map was created from existing information, and soil depths were measured. Historical analyses of *Melaleuca* infestation in both the entire Lakebelt region and eight sections of the study area were conducted by comparing digitized maps of aerial photographs from 1963 to 1992. Analyses of correlations between *Melaleuca* cover and soils, topography, and hydrology were performed.

Approximately 30% of the Lakebelt Region has been altered by man. Most of this activity, dominated by rock mining and agriculture, has occurred north of Okeechobee Road and along the eastern side of the study area. Natural cover types, the remaining 70% of the study area, are found primarily in the Pennsuco Wetlands and in the western areas along the Dade-Broward Levee. Prairie with varying degrees of *Melaleuca* infestation was the prevalent natural community type. Tree Islands and Willow Heads, the only indigenous wetland forested vegetation community types found, occupied less than 1% of the study area.

Of the 307 plant species found in the study area, 15 are categorized as threatened by the State of Florida. Nine are ferns and six are terrestrial orchids, all of them relatively widespread and common in southern Florida despite their threatened status. Two other species categorized as Commercially-Exploited by the State of Florida are relatively common in the Lakebelt Region. Five species of plants are categorized as Rare by Dade County, while four species are classified as Uncommon to Common. Two of the species protected by Dade County (listed as Uncommon to Common) are endemic in freshwater wetland areas in southern Florida.

Twelve soil types were identified. Lauderhill Muck, Depressional was the most common (57%) in the study area. Soil depths ranged from 22 to 132 cm. *Melaleuca*, which was almost absent in 1963, now covers approximately 45% of the study area, and the rate of expansion has been exponential. No correlation was found between *Melaleuca* expansion and soil type, soil depth, land elevation or hydrology. In portions of the Lakebelt Region, *Melaleuca* appears to be invading from east to west.

1.0 Introduction

1.1 Institutional setting: On April 8, 1992, Governor Lawton Chiles established the Northwest Dade County Lakebelt Plan Implementation Committee in order to evaluate a proposal by the South Florida Limestone Mining Coalition (SFLMC) to excavate approximately 30,000 acres of freshwater wetlands in northwest Dade County. To date, more than 4,000 acres of Northwest Dade County have been mined for the extraction of limestone. Each year about 300-400 acres of freshwater wetlands are converted to deep water lakes. The end result is a mosaic of individual lakes and artificially constructed wetlands (littoral areas).

On October 28, 1992, the U.S. Army Corps of Engineers (USCOE) extended an invitation to the agencies on the Lakebelt Plan committee to participate in the development of a programmatic Environmental Impact Statement for the proposed Lakebelt Plan. The Directors of the Dade County Planning Department and Dade County DERM were appointed to serve on the Committee.

Several studies were identified by the agencies as needed to properly assess the potential benefits and impacts of the proposed plan. The recommended studies included water quality and water quantity evaluations, an ecological impact assessment, and a land use planning evaluation.

The Department of Environmental Resources Management of Dade County (DERM) prepared a scope of services to evaluate the existing function and quality of freshwater wetlands within the Lakebelt Region. Existing vegetation had to be mapped and quantitative data had to be collected on wildlife populations using the area. These data were to be used to predict future environmental conditions under various planning scenarios involving the excavation of deep water lakes and the protection and enhancement of adjacent wetland areas.

EAS Engineering, Inc. was selected to conduct an inventory of the Lakebelt Region, to include: 1) mapping the region's vegetation, soils and topography, 2) analyzing the existing and historical distribution of the Australian melaleuca tree, *Melaleuca quinquenervia*; and, 3) examining the data for any correlations between *Melaleuca* distribution and soil type, topography or hydrology.

On March 26, 1995, EAS presented a Year 1 report on cover types and soil types (EAS Engineering, 1995a). On December 4, 1995, we presented a Melaleuca Expansion Rates report, and on December 14, 1995, we presented a Year 2 Final Report on the vegetation, soils, and mapping of the study area (EAS Engineering, 1995b). The present Final Report uses and refines the previously reported data and supersedes all of the previously submitted reports.

1.2 Geographical setting: The Lakebelt Region is a mixture of ecologically pristine, degraded, and developed areas covering approximately 48,000 acres. Its boundaries are the Dade-Broward Boundary/Snake Creek Canal to the north, Tamiami Trail to the south, the Homestead Extension of the Florida Turnpike to the east and Krome Avenue to the west (Figure 1).

1.3 Background

Since its introduction into South Florida in 1906, *Melaleuca* has become established in areas that were historically wetlands, especially those stressed by reduced hydroperiods. This species negatively impacts wetland function, thus threatening the core of the Everglades ecosystem. *Melaleuca* drastically changes ecosystem structure and dynamics. Forests replace gramineous marsh, thus changing animal use; leaf litter and woody debris change relative soil elevation and hence hydrology. Tree weight can compress underlying peat deposits; organic matter results in heavy fuel loads of very combustible materials, leading to very hot fires; higher leaf areas increase evapotranspiration and lower water tables; and leaf litter may produce allelopathic substances which, combined with dense evergreen shade, may eliminate understory species. For all this, *Melaleuca* has been declared a Federal Noxious Weed and a Florida Prohibited Aquatic Plant. These regulations prohibit its importation into the United States and its transportation throughout Florida, respectively (Bodle et al 1994). The spread of *Melaleuca* has been described as explosive with an accelerating rate of spread (Hofstetter 1991, Cost & Craver 1980, Laroche & Ferriter 1992).

Abiotic Factors: Abiotic factors that have influenced the current distribution of the cover types in the Lakebelt Region include (1) generalized historical alteration (lowering) of the water table associated with canal and drainage ditch excavations and berming; (2) rockmining throughout the eastern portion of the study area; (3) development and urbanization, including road building; (4) construction of high voltage electrical power transmission corridors; (5) construction and operation of a public wellfield; and (6) periodic uncontrolled wildfires that have historically ravaged the study area.

The primary effects of these abiotic factors in the study area have been to shorten hydroperiods and to disrupt and redirect surface water sheet flows from historical conditions. These modifications have resulted in the alteration of the historical long hydroperiod wetlands to shorter hydroperiod prairies, causing shifts in vegetative species composition and species richness. The rockmining industry has created extensive areas of deep water habitat, which do not naturally occur in southern Florida.

A secondary result of this human activity has been the creation of extensive areas of disturbed land which have been colonized by weedy and/or noxious exotic vegetation. Another byproduct of the ongoing rockmining is the creation of temporary shallow water bodies which are colonized by numerous wetland species.

Wildfires are a normal part of the cycle of the natural habitats within the study area. However, the alteration of hydroperiods and water levels, coupled with the extensive invasion of the area by *Melaleuca* (discussed below), and drought conditions which occurred in the late 1970s and late 1980s resulted in extremely hot wildfires in portions of the study area. In many areas the organic substrate burned down to the rock layer. These effects were particularly severe in the vicinity of the Northwest Wellfield. Furthermore, many of the tree island habitats have been severely impacted by wildfires, resulting in an invasion by exotic species and shrinking of the areas covered by tree islands.

Biotic Factors: The principal biotic factor affecting the study area is the rapid colonization of prairie wetland habitats by the noxious exotic tree *Melaleuca*. *Melaleuca* expansion in the Lakebelt Region has been identified as a primary environmental concern. This study was designed to shed more light on the rate of *Melaleuca* expansion and to try to determine what factors might be affecting it.

2.0 Methods

2.1 Vegetation and soils

2.1.1 Vegetation: During the formulation of the Lakebelt Study, an interagency task force defined eighteen categories of cover types that would be delineated during the vegetation mapping phase of the project. Those cover types were divided into two basic groups, natural cover types and man-altered cover types.

Natural cover types comprise a spectrum of jurisdictional (Florida Department of Environmental Protection, South Florida Water Management District, Dade County Department of Environmental Resources Management, and U.S. Army Corps of Engineers) wetland prairie associations that were assigned to one of four categories, based on the degree of invasion by *Melaleuca*: <10% *Melaleuca*; 10%-50% *Melaleuca*, 50%-75% *Melaleuca* and Dense *Melaleuca* (75%-100%). Dense Melaleuca Saplings (DMS) was a category added later to include prairie areas having a dense canopy of small *Melaleuca* saplings. Also among the natural cover types are forested Willow Head and Tree Island communities.

Prairie (P): Except for Dense *Melaleuca*, the prevalent community type within the Lakebelt Region is prairie, which includes both short hydroperiod (three to six months) and longer hydroperiod (six to nine months) wet prairie communities dominated by graminoids and other herbaceous species, occurring on muck-dominated soils (Richter et al., 1990). In the Pennsuco wetlands west of the Dade-Broward Levee, the hydroperiod ranges from six to nine months (ibid). Within the majority of the Lakebelt Region, the graminoid Sawgrass (*Cladium jamaicense*) is the dominant indigenous species of this prairie community, with patchy areas, especially in the southern areas of the Lakebelt Region containing a significant component of one or more of the following graminoid species: Beardgrass (*Andropogon glomeratus*), Broomsedge (*Andropogon virginicus*), Sheathed Cyperus (*Cyperus haspan*), Erect Panicum (*Dichanthelium erectifolium*), White Top (*Dichromena colorata*), Spikerush (*Eleocharis cellulosa*), Elliott's Lovegrass (*Eragrostis elliottii*), Sugarcane Plumegrass (*Erianthus giganteus*), Muhly (*Muhlenbergia capillaris*), Red Top Panicum (*Panicum rigidulum*), Bluejoint Panicum (*Panicum tenerum*), Spreading Beakrush (*Rhynchospora divergens*), Littleseed Beakrush (*Rhynchospora microcarpa*), Tracy's Horned Rush (*Rhynchospora tracyi*), and Narrow Beardgrass (*Schizachyrium* *rhizomatum*). Common herbaceous components of this community include Coinwort (*Centella asiatica*), String Lily (*Crinum americanum*), Oak-leaved Fleabane (*Erigeron quercifolius*), Fennel (*Eupatorium leptophyllum*), Yellowtop (*Flaveria linearis*), Marshelder (*Iva microcephala*), Creeping Charlie (*Phyla nodiflora*), Marsh Fleabane (*Pluchea rosea*), Swamp Mermaid (*Proserpinaca palustris*), and Water Pimpernel (*Samolus ebracteatus*). Numerous other herbaceous and graminoid species are present in this community. There is substantial patchiness of plant species within this prairie community, attributable to differences in soil type and depth, surface water depth, and perturbation factors.

Within the prairie community, indigenous tree and shrub species occur sporadically. The most prominent species include Buttonbush (*Cephalanthus occidentalis*), St. Andrew's Cross (*Hypericum fasciculatum*), Dahoon Holly (*Ilex cassine*), Wax Myrtle (*Myrica cerifera*), and Swamp Bay (*Persea palustris*). Coverage of Melaleuca in this habitat type is less than 10%.

Also within the prairie community, and most prominently in the prairies of the Pennsuco Wetlands, is a subcommunity type called "flats" which is quite different both floristically and structurally from the surrounding prairie. Flats tend to be very small and dominated by herbaceous and graminoid species but do not include Sawgrass. The vegetation is usually substantially shorter and less dense than in the surrounding prairie. Periphyton usually attains its greatest development in the flats subcommunity type. Netted Shy-leaf (*Aeschynomene praetensis*), String Lily, Spikerush, and Tracy's Horned Rush are among the most common species in these areas.

Prairie with *Melaleuca:* *Melaleuca* has invaded the prairie wetlands very extensively in southern Florida, and occurs in varying amounts throughout the study area. P50, or prairie with 10% to 50% *Melaleuca* retains its primary vegetative character as prairie, with only minor diminishment in species richness and dominance of graminoid and herbaceous vegetation. This habitat is characterized by relatively open areas, with small stands of *Melaleuca* scattered randomly throughout the area.

P75, or prairie with 50% to 75% *Melaleuca*, also retains some of its prairie characteristics, but there is a more noticeable loss of species richness and dominance by herbaceous vegetation.

Dense *Melalaleuca* Forest: *Melaleuca* has attained forest stature or density in many areas of the Lakebelt Region. Two categories of so-called dense *Melaleuca* have been mapped for this study.

Dense *Melaleuca* Forest (DM) is a closed canopy stand of Melaleuca which can attain heights of 30 to 40 feet. Within these stands, the density of trees can vary from relatively open to very dense thickets. By definition, these areas range from 75% to 100% *Melaleuca* canopy coverage. The understory is very sparse, and contains a few of the prairie species, most of which exhibit etiolation and other signs of diminished light levels. The most common understory species are Royal Fern (*Osmunda regalis*), Swamp Fern

(*Blechnum serrulatum*) and Shield Ferns (*Thelypteris* spp.). Occasional Wax Myrtles, Red Bays, Dahoon Hollies and *Baccharis* spp. are also found in the understory.

Dense *Melaleuca* Saplings (DMS) refers to *Melaleuca* forest that has attained only a height of about 15 feet or less. It is characterized by having an extremely high stem density and, consequently, there is liTtle opportunity for other species to occur in this habitat. Most of this habitat represents areas where *Melaleuca* is recovering from the hot wildfires of 1990. DMS was identified in the aerial photographs as follows: if individual mature trees could be identified in areas whose signature corresponded to dense Melaleuca, then it was classified as DM; if no individual trees were discernable, then it was classified as DMS.

Tree Islands and Willow Heads: These are the only two categories of indigenous wetland forest habitat in the Lakebelt Region.

Tree Islands (TI) are dominated by Red Bay, Coastal Plain Willow (*Salix caroliniana)*, Brazilian Pepper (*Schinus terebinthifolius*), West Indies Trema (*Trema micrantha*), Groundsel Tree (*Baccharis glomeruliflora*), Shrubby Waterprimrose (*Ludwigia octovalvis*) and Wax Myrtle. Numerous other species of trees, shrubs and ground cover are also present in the tree island habitat.

Willow Heads (WH) are areas dominated by Coastal Plain Willow.

Man-altered cover types comprise water bodies (canals, lakes, impoundments, temporary ponding, etc.), modified habitats (agriculture, lake perimeter or scarified areas surrounding lakes), developed areas, disturbed prairie, disturbed prairie with 10%-50% *Melaleuca*, disturbed prairie with 50%-75% *Melaleuca*, vegetated disturbed areas (some of which are not jurisdictional wetlands), and the Florida Power & Light high voltage transmission lines which occur within the study area. The "disturbed prairie" category refers to prairie whose soils were modified in the past by human activities, such as rock plowing, mowing or cattle grazing, but which are again developing wetland characteristics.

Lakes (L) include all of the quarry lakes associated with limestone mining. These lakes are up to 60 feet deep and most of them contain no vascular plants.

Lake Perimeter (LP) includes the cleared, unvegetated work areas surrounding the quarry lakes.

Canals (C) consist of canals, ditches and other excavated water bodies which contain at least some standing water all year round. This cover classification includes the Dade-Broward Levee, which separates the western third of the Lakebelt Region from the eastern two-thirds. It also includes the Tamiami, Miami and Snapper Creek canals. Cattails (*Typha dominigensis*) and Spatterdock (*Nuphar luteum*) typically dominate canal habitats.

Other Water (W) includes shallow impoundments and temporary ponds which are associated with ongoing rock mining and which occur in and around lake perimeters. It also includes a number of wetland mitigation ponds. They are often vegetated with a variety of annual and short-lived wetland species that tolerate extremes of fluctuating water levels. Typical species associated with this cover type are Matted Figwort (*Bacopa monnieri*), Tropical Flatsedge (*Cyperus surinamensis*), Purple Spikerush (*Eleocharis atropurpurea*), Hurricane Grass (*Fimbristylis spathacea*), Umbrella Sedge (*Fuirena breviseta*), Marsh Pennywort (*Hydrocotyle umbellata*), Large-headed Rush (*Juncus megacephalus*), Shrubby Water Primrose, Fall Panicum (*Panicum dichotomiflorum*) and Marsh Fleabane (*Pluchea odorata*).

Agriculture (AG) includes pasture, improved pasture, tree farms and nurseries, sugar cane fields and other row crops.

FPL Right-of-Way (FPL) was distinguished as a separate cover type because it is kept clear of *Melaleuca* by periodic maintenance, but otherwise is left as functioning wetland habitat. The FPL right-of-way divides most of the Lakebelt Region in a north-south direction.

Developed Areas (DV) include all areas that have been developed for commercial, institutional or residential use, including roads, buildings, parking lots, etc. Vegetation in these areas usually consists of exotic landscaping plants, with exotic and nuisance species dominating fencelines and other poorly maintained areas.

Disturbed Areas (D) include both forested and open upland areas that have been modified by man. Forested disturbed areas are dominated by noxious, exotic vegetation such as Brazilian Pepper, *Melaleuca*, Australian Pine (*Casuarina equisetifolia*), Beefwood (*Casuarina glauca*) and the indigenous West Indies Trema. These areas usually include canal berms, roadside vegetation, and abandoned fields. The open disturbed land has no forest canopy, but can be heavily overgrown by shrubby, weedy vegetation. It includes roadside areas, portions of active rock quarry operations and old abandoned fields.

Disturbed Prairie (DP), Disturbed Prairie with Melaleuca (DP50) and Disturbed Prairie with Melaleuca (DP75) include those areas that were cleared in the past (by mowing, plowing, grazing, etc.) but are now reverting to prairie wetlands, with levels of *Melaleuca* infestation similar to those described above for the natural prairie cover types.

Cover types were digitized from Dade County 1:3600 (1"=300') uncontrolled, black and white aerial photographs (1992 and 1994) by an EAS AutoCad specialist who was trained to identify their different signatures by the same experienced field biologist who identified and ground-truthed the cover types. Eighty-one aerial photographs were digitized - one for each section in the Lakebelt Region (Figure 2). Cover types were identified by their "signatures", i.e. the grey scale and texture of the area on the photo. Individual trees and the edges of stands of tall trees could be identified by their shadows. Different types of forest, e.g. Brazilian Pepper (*Schinus terebinthifolius)*, Australian Pine (*Casuarina* *equisetifolia*) and *Melaleuca*, have distinctive textures that can be recognized with practice. Deep, clear lakes are dark; shallow or turbid water is light. Periphyton gives prairie a mottled appearance. Grazed pasture has a very smooth, even texture, with individual trees standing out in contrast. The neat, linear features of row crops and tree farms are readily apparent.

It should be noted that this vegetation mapping effort was undertaken to assist in the planning of a large scale project (almost 50,000 acres). The information presented in this document should not be used for site-specific permitting decisions. Independent vegetation mapping at a scale suitable for the individual project should be required for permitting purposes.

Once all of the aerials had been digitized and merged, the AutoCad drawing was converted into a GIS (Geographic Information System) ArcInfo coverage for analysis and display. Minor spatial adjustments were made to the coverage using features digitized from USGS Quad Sheets and several reference locations identified with GPS (Global Positioning System) equipment. These adjustments were necessary to correct the distortions and frequent lack of control points on the Dade County aerials.

Despite the fact that a number of cover types could be distinguished fairly readily on the aerial photographs, there were areas that were difficult to identify with certainty. Access to much of the area was very difficult. Some areas were visited by ground crews as part of this study, primarily the twelve Everglades Research Group wildlife stations, two tree islands and a large area of P50. Mark McMahon, of Biological and Environmental Consulting, had visited other areas of the Lakebelt Region during previous studies. All of these ground-truthing sites are shown in Appendix A.

The majority of the ground-truthing effort consisted of a helicopter overflight covering the entire study area. The helicopter ground-truthing was conducted toward the end of the Year 1 mapping effort, after all of the cover types had been digitized, converted to a GIS coverage and attribute- coded for their cover type. The entire Lakebelt area was flown in an east-west direction along section lines. Individual sections were circled when necessary to clearly determine their characteristics. Several times the helicopter landed to verify observations made in the air. As a result of this effort, many changes were made to the maps. Polygons were added and eliminated and cover type assignments were changed. This effort consumed over six hours of flight time. This aerial "truthing", in our opinion, provided us with much better spatial coverage of the Lakebelt Region than could be covered from the ground. The aerial effort also allowed us to get a good perspective on the homogeneity, or lack thereof, of the various cover types.

During the analysis of historical changes in cover type described below, it became apparent that some features, such as canals and tree islands, had been obscured by other types of vegetation in the 1992 aerials and therefore were not correctly represented. Canals, for example, were often obscured by overhanging forest canopy - often Brazilian Pepper or Australian Pine growing on the canal banks - and had therefore been recorded as "Disturbed". Tree Islands in a number of cases had been confused with *Melaleuca* because the signatures are not very different. This was corrected by reviewing the earlier aerials and modifying the 1992 coverage accordingly.

Canals: Our 1963 coverage was compared with a Canal coverage provided by DERM. For any area where a canal was missing from the 1963 coverage, but present in the DERM Canals coverage, the aerials were consulted. If evidence of a canal was present, the canal was digitized into the coverage. It was assumed that if a canal was present in 1963, it was still present in the 70's, 80's, and 90's, even though vegetation might obscure it in the aerial photo. All such canals were added to the subsequent coverages.

Tree Islands: If Tree Islands were present in our 1963 coverage, we re-examined the aerials for the 70's, 80's, and 90's for those very same locations, in order to verify whether or not that cover type was still present.

Although the Year 1 report was intended to present existing conditions in the Lakebelt Region, the findings in the Year 1 report were refined during the historical analysis as described above. These adjustments are reflected in the data presented on the right hand side of Table 1 (Previously Reported Acreages). The Year 1 data summary is superseded by this report.

In January, 1996 DERM provided us with their Level II Arc/Info export files for Edge-of-Pavement, Centerlines, and Water Bodies for the Lakebelt Region and asked us to adjust, or "rubbersheet", our current lakebelt coverage to the Edge-of-Pavement. Two or three initial rubbersheeting adjustments were performed by linking permanent, unmistakable features such as road intersections, especially along the borders of the Region. Then, section by section, the coverage was examined for agreement of DERM's edge-of-pavement with our roads, and adjusted manually by moving and/or re-drawing when necessary. Aerial photographs were constantly referred to during this process as a double check against incorrect alterations to shape or cover-type assignment. Roads in DERM's coverage were added to our coverage, when the aerials confirmed that they were present but had not originally been digitized, unless the roads were part of a Lake Perimeter and were not distinguishable from surrounding scarified cover. Canals were also added, as well as other water bodies, if their presence could be confirmed on aerials. Table 1 compares the recent corrections in cover type acreages with the values previously presented in the Year 2 Report (EAS Engineering, 1995b). The differences are negligible. All of the analyses presented in this report were based on the earlier coverages because the corrections were continuing while the analyses were being performed.

During the course of this study, separate contracts were awarded to the Everglades Research Group and to Nova Southeastern University Research Group to examine the wildlife and littoral flora and fauna in the Lakebelt Region, respectively. The locations of the sampling stations for those studies are shown in Figure 3. The wildlife stations were established in such a way as to be able to relate habitat utilization by wildlife to cover types identified in this report. During the final stages of this study, it had become apparent that several cover type designations assigned by the Everglades Research Group (ERG), which was performing the wildlife analysis, differed from those of EAS. Those discrepancies are discussed in Appendix B.

2.1.2 Plant species: While conducting the ground-truthing and the other field measurements described in this report, a list of plant species observed in the field was compiled (Appendix D). We also noted relative abundance, federal and State wetland status, the types of habitat where they were most commonly found, and the level of protection given to the rarer species by different agencies.

2.1.3 Soil types: The coverage for the Lakebelt Region Soil Types was created from DERM's Arc/Info export file LB_SOILS.e00. This coverage was clipped to the extent of EAS' Lakebelt coverage. The EAS coverage was used to update the water bodies (soil type 'Water' in DERM's soil coverage) because EAS' coverage was more recent. Soil type designations follow those of SDSWCD (1994).

2.1.4 Soil depths: For this study, soil depths were measured in 1994 and 1995 in sections 21-53-39 and 4-53-39 (Tree Islands) and in Section 16-53-39 (P50) as well as at twelve of the Environmental Research Group's wildlife stations in Sections 10, 15, 20, 27, 28 and 29 of Township 52 South, Range 39 East.

Soil depths were measured during GPS data collection at the twelve wildlife stations. Five probes were made in the vicinity of each station using a calibrated steel rod. Depths were also measured at one P50 station and two tree island (TI) stations along transects established in each cover type, with replicate probes made at approximately 100 meter intervals along each transect. The replicates were averaged at each station.

Since most of our ground-truthing was done by helicopter, which prevented us from gathering more exhaustive data, we present supplemental data in Appendix H: soil depths taken in 1987 in Section 21-53-39 (Cappelletti Brothers), 23-52-39 and 33-53-39 (Rinker) in 1990, 1991, and 1992 respectively, all of them taken in conjunction with HEP analyses performed to support mining applications. Soil depths measured during a 1987 Special Area Management Plan (SAMP) study of four sections: Govt. Lot 6-53-39 and Sections 6-53-39, 20-52-39, and 20-53-39 (Richter et al., 1990) are also provided in Appendix H. Soil depths in the studies presented in Appendix H were probed along measured transects established in different cover types. Most transects were 100 m long with measurements made every 10 m. Soil depths were measured by inserting a PVC rod perpendicularly into the soil until it hit bed rock. After retrieving the rod, the distance between the end of the rod and the mud mark was measured with a tape measure. Surface water level was not taken into consideration when recording soil depths. Much of this ancillary soil depth data could not be applied to this study because the cover type categories do not match the categories used in this study, however the soil depth is presented by section in Appendix H.

2.2 Existing and historical *Melaleuca* distribution

Melaleuca expansion was examined using two different approaches: a region-wide study and a more intensive analysis of eight representative sections.

2.2.1 Region-wide study: Cover type changes over four decades were studied by comparing the digitized coverages created from aerial photographs of the entire Lakebelt Region. Beginning in 1963 (the year in which Dade County began its county-wide systematic aerial photographic coverage), 81 aerial photographs, one for each section within the Lakebelt Region, were obtained for each decade. The representative years chosen were 1963, 1975, 1984, and 1992. In Figure 9 and Tables 4 and 4a, the time periods are presented as decades (1960's, 1970's, etc.). For the graphics (Figure 10) and statistical analyses, however, the actual years were used as the "time" variable.

Because of the large scale of this analysis (324 aerial photos, one square mile each) and the inability to ground truth historic aerial photos, a reduced set of cover types was used. The 18 cover types used to inventory vegetation and land use were reduced to six:

1) *Melaleuca* Less than 50% (ML50). Relatively open areas with small stands of *Melaleuca*, 0-50%. It includes Prairie (P), Prairie with *Melaleuca* (P50), Willow Heads (WH), Disturbed Prairie (DP), and Disturbed Prairie with *Melaleuca* (DP50).

2) *Melaleuca* (M). Medium to dense *Melaleuca* cover, >50%. This cover type includes Prairie with *Melaleuca* (P75), Dense *Melaleuca* (DM), Dense *Melaleuca* Saplings (DMS), and Disturbed Prairie with *Melaleuca* (DP75).

3) Tree Island (TI). The same as for the vegetation study.

4) Disturbed Areas (D). Primarily upland areas, including canal berms, roadsides in areas of old fields that have been allowed to return to a forest-type habitat, and rock mine spoil areas that have been allowed to revegetate. It resulted from grouping Disturbed, Forested and Open (D), Lake Perimeter (LP), Agriculture (AG), FPL Transmission Corridors (FPL), and Developed (DV).

5) Canals (C). The same as for the vegetation study.

6) Lakes (L). A combination of Lakes (L) and Other Water (W).

Figure 4 shows the Lakebelt Coverage for 1992, with its original 18 cover types merged to form the above six cover types.

Once the cover types were identified and their boundaries marked on the aerials, each aerial was digitized using AutoCAD r.12/13 and converted to an Arc/Info version 7.0.3 coverage. For 1992, the coverage used was that of the vegetation study described above, but reduced to the six cover types chosen for this aspect of the study.

After the preliminary results of the wildlife studies became available, it was suggested that the 50% cutoff point for *Melaleuca* coverage might not be an appropriate threshold from a wildlife perspective. The most noticeable changes in wildlife use of prairie habitat seemed to occur only after *Melaleuca* attained a canopy of 75%. It was therefore suggested that we modify the analysis of *Melaleleuca* expansion over time using <75% and >75% cover as categories rather than <50% and >50%. To see how this would affect the outcome, the Lakebelt coverage for 1992 was reclassified into the 6 categories described above, but this time using a 75% cut-off point for dense *Melaleuca*. Maps of the 50% and 75% levels are compared in Figure 5 and the cover type areas are summarized in Table 2. This analysis revealed that there was very little difference in the two coverages. There was approximately a 10% shift of acreage from dense *Melaleuca* to ML75 (approximately 4,000 acres) after the change. Most of the change occurred in the southwest corner of the study area and in the northern area lying east of the Dade-Broward levee and south of Okeechobee Road. An examination of the historical aerials used in this study revealed that our digitization of the aerials was done fairly conservatively, i.e. the lines separating ML50 from DM were usually drawn somewhere between ML50 and ML75. It was therefore decided to continue the study using 50% cover as the cut-off threshold.

2.2.2 Selected sections study: To analyze in greater detail the vegetation changes through time, eight representative sections were chosen by the interagency scientific committee, in cooperation with the wildlife researchers: 5-52-40, 22-52-39, 30-52-39, 4-53-39, 12-53-39, 28-53-39, 29-53-39, 5-54-39 (Fig. 6). These sections were not chosen randomly, and therefore must not be considered to be a subsample of the entire Lakebelt Study Area for statistical purposes. They were intended to represent the wide range of geographical and environmental settings found within the region. Selection criteria also included the relative amount of development occuring in the sections (minimum development was desirable) and the relative amount of *Melaleuca* occurring in each section by 1992. Since the objective of this study was to analyze *Melaleuca* expansion over time, it was necessary that the selected sections have some *Melaleuca* in them by 1992.

Eight aerials, at intervals approximating three years, were digitized for each section except for sections 5-52-40 and 5-54-39 where only seven were used. The intervals were not uniform because selection of aerials was based on availability and quality of the aerials. The first interval, from 1963 to 1971 (Table 3) was the longest, due to the absence of *Melaleuca* and the lack of regular aerial coverage in the undeveloped portions of Dade County during the earlier years. Other aerials were rejected because they were not clear enough to identify the vegetation, or showed burn scars from wildfires, which obscured the vegetation.

For ease of comparison in Figure 12 and Tables 5 through 12, the "reference years" shown in Table 3 were used to identify the eight time periods. For the graphics and statistical analyses, however, the actual year in which each aerial was flown was used as the "time" variable.

For the regression analyses, acreage of dense *Melaleuca* (>50%) was converted to percent cover to make the data comparable, since the total acreage was not the same for all eight sections. Section 5-54-39, for example, was only a partial section. To eliminate the effects of development, which was occurring in most of the sections during this time period, percent cover for each year was based on the total acreage of undeveloped land in the 1992 coverage for each section, namely, Tree Island (TI) + Prairie with <50% *Melaleuca* (ML50) + Prairie with >50% *Melaleuca* (M). This would tend to overestimate *Melaleuca* invasion rates in the early years before the development occurred, but it would make the data more accurate for the later years, since lakes, canals and some disturbed areas (e.g. developed areas, agricultural areas and lake perimeter) are not potential *Melaleuca* habitat. This approach is consistent with that used by other authors (Laroche & Ferriter, 1992).

2.3 Topography

Elevation contours for the Lakebelt Region were extracted from DERM's AutoCad drawing SFALL.DXF, which was based on a topographic survey conducted for the South Florida Water Management Districty by James Beadman & Associates, Inc. Canals and lakes were added from the 1992 Lakebelt coverage shown in Figure 8. A polygon coverage was created from the elevation contours in one foot increments, except for the 4.0 foot contour, which was incomplete. This coverage does not include the area north of U.S. 27 (Okeechobee Road) because no elevation data were available for that area.

2.4 Hydrology

Annual means of groundwater elevation from 1963 to 1992 for six wells within the Lakebelt Region were obtained from the U.S. Geological Survey (USGS). The wells were G-970, G-972, G-974, G-975, G-976 and G-1488 (Fig. 7). The groundwater elevations for each of those wells were assumed to be representative of the closest of the eight sections chosen for the *Melaleuca* expansion analysis and were matched as follows: G970/5-52-40; G972/22-52-39; G975/30-52-39; G974/12-53-39; G1488/29-53-39; G976/28-53-39 (Fig. 7). Monthly average groundwater levels were calculated for the period 1980 to 1992 and ground elevations at the wells were estiimated using the topographic data discussed in Section 2.3.

2.5 Statistical Analyses

The statistical analyses presented in this report are limited. Contractual and budgetary restraints did not allow us to conduct a thorough statistical analysis. Our analyses were intended only to quantitatively describe the trends we saw in *Melaleuca* expansion over time and to see if any correlations were evident which might explain this expansion. Simple, linear regression and correlation analysis were proposed, rather than more sophisticated, but more technically demanding methods such as polynomial regression or multivariate analysis. Nor were the data tested to determine whether they met the assumptions of regression, namely, linearity, independent and normally distributed Y values, and homoscedasticity (constant variance). Such analyses were beyond the scope of this project.

Statistical analyses included linear regression, analysis of variance (ANOVA) and correlation analysis. SYSTAT for Windows, Version 5 was used for this analysis and for producing the graphs. Transformations were used to improve the linearity of the data if a linear regression failed to show a significant slope. Two transformations were applied: a square root and a log normal transformation.

A probability level of $p = 0.05$ was used to reject or accept null hypotheses. The computer outputs for all statistical analyses are presented as appendices, including regressions that were rejected as being not statistically significant.

Because of the small sample size (four data points for the regionwide analysis of *Melaleuca* expansion and seven or eight points for each of the representative sections), it was decided not to extrapolate the regression formulas for *Melaleuca* expansion beyond the last measurements in 1992 (i.e. prediction of future outcomes).

3.0 Results

The 1992 map of Lakebelt cover types is presented in Figure 8 and the acreage and percent contribution of each cover type are summarized in Table 1. Table 1 also compares the recent corrections in the coverages with those reported in the Year 2 Report (EAS Engineering, 1995b) as discussed in the introduction. The differences are negligible, and all of the analysis that follows is based on the previously reported data on the right hand side of Table 1. Individual maps showing the distribution of each cover type are presented in Appendix C.

Approximately 70% of the Lakebelt Region consists of natural cover types and 30% has been altered by man. The man-altered cover types tend to occur north of Okeechobee Road (U.S. 27) and along the eastern third of the study area, while the natural cover types dominate in the western two thirds of the region.

3.1 Natural cover types

Dense *Melaleuca* (DM) is the most abundant cover type, accounting for 22.2% of the total Lakebelt Region. Prairie (P) is the next largest component of the region, with 15.5% of the total. The distribution of the two covertypes (Appendix C) shows that dense *Melaleuca* dominates the eastern two-thirds of the region, while prairie is dominant in the western one-third, between the Dade-Broward levee and Krome Avenue. Small pockets of prairie also remain north of Okeechobee Road and in the southeast corner of the Lakebelt Region.

Prairie with *Melaleuca* (P50 and P75 combined) accounts for 17% of the region, and these two cover types dominate the central part of the region, on both sides of the Dade-Broward levee. This reflects the fact that these cover types are intermediate stages in the succession from prairie to *Melaleuca*. Very little P50 or P75 is found along the eastern edge of the Lakebelt.

Dense *Melaleuca* saplings (DMS) are concentrated in the central area of the region within a two mile radius of the Northwest Wellfield. This cover type occupies 14% of the region.

Scattered tree islands (TI) and willow heads (WH) occupy a very small proportion of the Lakebelt Region (less than 1% combined).

3.2 Man-altered cover types

Lakes (L) are predominant among the man-altered cover types, accounting for 9.4% of the Lakebelt Region. Most of the lakes are located in the eastern 1/3 of the region, both north and south of Okeechobee Road. Much of the Lake Perimeter (LP) and Disturbed (D) cover types also represent land associated with rock mining operations (the areas surrounding the lakes). These cover types account for another 7.7% of the region.

Agriculture (AG) is another important component of the man-altered cover types, accounting for 6.5% of the region. Most of the agricultural land is located at the north end of the Lakebelt Region, but a few agricultural areas are also found in the southeast corner.

The developed (DV) cover type includes institutional uses such as correctional facilities, the Northwest Wellfield, and roadways. Less than 3% of the Lakebelt Region is developed.

The FPL powerline (FPL) occupies 2.9% of the region. The remaining cover types occupy 1% of the total area or less. Other Water (OW) accounts for 1% and canals (C) account for 0.7% of the region. The disturbed prairie cover types (DP, DP50 and CP75) appear to be associated with the agricultural areas at the northern end of the Lakebelt Region. Combined, however, they only occupy slightly more than 1% of the region.

3.3 Plant species

Appendix D presents a complete list of the vascular plant species observed in the Lakebelt Region during numerous field trips over the course of the study. Next to each species is its relative abundance, its wetland status with FDEP and the Army Corps of Engineers, the habitat type in which the species is most commonly found, and its status on State and federal rare and endangered plant species lists.

Of the 307 species listed, fifteen are classified as Threatened by the State of Florida. Nine of these are ferns that are relatively widespread and common in South Florida. Six are terrestrial orchids that are also relatively common in South Florida. The

State of Florida lists all ferns and orchids in this State, regardless of their local status (Mark McMahon, 1996, pers. comm.). Two categorized as Commercially-Exploited in Florida are also relatively common in the Lakebelt Region. No federally listed plant species were observed in the Lakebelt Region, nor are any of the plants found in the Lakebelt truly endangered or threatened (Mark McMahon, 1996, pers. comm.).

3.4 Increase in *Melaleuca* cover over time - Regionwide

Changes in cover type distribution over time are shown for the entire Lakebelt Region in Figure 9 and are summarized in Tables 4 and 4a. In the 1960's, 92% of the area was prairie with less than 50% *Melaleuca*. The 1970's saw an increase in the amount of disturbed land from 5.5% to 9.5%, the beginnings of rock quarrying (up from 0.1% in the 1960's to 4.8% in the 1970's) and a reduction of tree island and prairie as *Melaleuca* now dominated almost 5% of the region. In the 1980's, disturbed land, lakes and dense *Melaleuca* continued to increase while prairie and tree islands decreased. The same progression continued throughout the 1990's, at which time *Melaleuca* dominated approximately 45% of the entire Lakebelt Region.

The increase in dense *Melaleuca* is presented graphically in Figure 10. The annual increase in cover is exponential, which is what one would expect during the early stages of population growth. A single tree dispersing its seeds outward creates a small stand of trees after a few years. If growth is unconstrained, this stand continues to grow outward from its edges as succeeding generations of trees cast their seeds outward. The rate of growth is linear if viewed in a single dimension (as in a cross section of the stand), but in terms of area, the rate is exponential. As time passes, natural obstacles to growth are encountered and the growth rate decreases. Such obstacles could include man-made barriers such as roads and canals, or simply the fact that the growing *Melaleuca* stand meets the edge of an adjacent stand and no further expansion occurs along that edge. The resulting growth curve is normally sigmoid in shape.

Laroche and Ferriter (1992) reported a three-phase, sigmoid growth pattern for *Melaleuca* studied in Dade and Broward Counties. The first phase was a log growth phase, followed by linear growth, and finally ending with a declining rate of increase. They presented a regression formula for a sigmoid curve to describe this growth:

$$\% \text{ Infestation} = 97.91 / (1 + 77.52 \times 0.74^{\text{YEAR}})$$

Due to contractual and budgetary restraints, polynomial regression was not feasible in this study. Instead, linear regressions were calculated for the data using log normal and square root transformations, as well as the untransformed data (Appendix E). As expected, the square root transformation yielded the best fit ($p = 0.016$). The regression formula and the regression curve are shown in Figure 10. Regression statistics for these data are presented in Appendix E. The r^2 value for this regression was 0.969, indicating an excellent fit.

3.5 Increase in *Melaleuca* cover over time - in eight representative sections

Figure 12 shows the changes in cover over time for each of the eight sections used for this analysis. The data are summarized in Tables 5 through 12. Figure 13 shows the increase in dense *Melaleuca* (>50% cover) over time in each section graphically. The percentages shown in Figure 13 represent the percent of the total potential *Melaleuca* habitat available in 1992 (total area minus lakes, canals and disturbed areas) as discussed in the Methods section. They therefore do not agree with the percentages presented in Tables 5a through 12a, where the acreage of each cover type is represented as a percent of the total area in each section.

Four of the sections, 5-52-40, 12-53-39, 22-52-39 and 28-53-39, show a marked increase in dense *Melaleuca* beginning as early as the late 1970's. The first two reached 50% cover by 1985. Section 28-53-39 appears to have experienced a ten year period, from 1976 to 1986, during which dense *Melaleuca* expansion was arrested. All four sections show anomalous "dips" in the graph during the 1980's, presumably due to apparent loss or redistribution of this cover type resulting from wildfires.

The remaining four sections show a lag of 15 to 20 years before dense *Melaleuca* exceeds 20% of the total available area. Two of those sections, however (4-53-39 and 5-54-39), were virtually completely covered by dense *Melaleuca* by 1992. Sections 30-52-39 and 29-53-39, both of which are west of the Dade-Broward levee, showed no appreciable dense *Melaleuca* until 1992, but the increase in *Melaleuca* coverage in 1992 is dramatic, particularly in Section 29-53-39. From 1989 to 1992, dense *Melaleuca* in this section increased from less than 1% to almost 60% cover.

Figure 14 presents the regression curves and formulas for the five sections for which significantly significant regressions could be calculated. Four of those had to be transformed before the assumption of linearity could be satisfied; one using the square root transformation and three using a natural log transformation. Regression statistics are presented in Appendix F.

The regression curves in Figure 14 fit fairly well, as indicated by the high r^2 values. Sections 30-52-39, 29-53-39 and 5-54-39 could not be fit with statistically significant regressions using either the log or square root transformations. This is most likely because of the long lag periods, followed by very rapid increases in dense *Melaleuca*.

3.6 Soil types and depths

3.6.1 Soil Type

Soil type distribution in the Lakebelt Region is presented in Figure 15, along with the locations of the soil depth stations used in this study. Those stations include ten established by the Everglades Research Group and three established by EAS Engineering.

Table 13 summarizes the acreages of each cover type found in each soil type. Lauderhill Muck is the predominant soil type, occupying 57.6% of the study area. All of the muck soils, combined, account for 84% of the total study area. Urban soils

(Udorthents) occupy less than 5% of the study area.

Soil distribution shows very distinct patterns. Most of the Dania Muck, for example, occupies the area north of Okeechobee Road, and most of the Pahokee Muck is found in a large, rectangular area west of the Dade-Broward levee. The three marl soils (Biscayne Marl, Biscayne Marl-Rock Outcrop Complex and Perrine Marl) are all located in the southeast corner of the region, although small marl pockets (less than ½ acre) were noted at some of the Everglades Research Group's wildlife stations in the northern part of the Lakebelt Region (Mark McMahon, 1996, pers. comm.). The udorthents are all concentrated around the rock quarries. Note that Demroy Muck was excluded from Figure 15 because this map unit was too small to be visible at this scale.

Table 13a presents the percentage of each cover type occupying each soil type. The muck soils, which constitute about 84% of the entire Lakebelt Region, contain almost all of the *Melaleuca*. To test whether there is any relationship between soil type and cover type distribution, it was necessary to factor out the large differences in area occupied by the different soils. If distribution is random, then the area of any cover type occupying a given soil type should be proportional to the total area occupied by that soil type. To test this, the acreage of each cover type occupying each soil type was regressed against the acreages of the soil types. The results yielded very significant positive regression ($p < 0.01$) for all cover types (Appendix G). The r^2 value for dense *Melaleuca* (M) was 0.976. This indicates that the acreage of dense *Melaleuca* occupying the different soil types is a function of the relative abundance of that soil type.

3.6.2 Soil Depth

Soil depth data collected for this study are shown in Table 14. Additional data from other studies, which could not be included in this analysis because of inconsistencies in cover type classification systems, are presented in Appendix H.. Figure 16 is a "whisker" graph showing the range of soil depths for each of the six cover types where soil depth was measured. For each cover type, the median value for soil depth is represented by the center horizontal line (DM is an exception because there were only five measurements). The median splits the ordered sample population in half, and the "hinges" (the boxes above and below the median) split the remaining halves in half again. The "whiskers", or vertical lines above and below the boxes, indicate the range of values falling within 1.5 "Hspreads" of the "hinges". "Hspread" is the difference between the values of the two "hinges". The circle for DM indicates a value far outside the other values. Soil depths in all cover types ranged from 22 to 132 cm.

Analysis of variance revealed significant differences among the soil depths in different cover types. A Tukey pairwise comparison revealed that soils in the dense *Melaleuca* sapling (DMS) cover type are significantly shallower than in any of the other cover types. Dense *Melaleuca* (DM) and prairie (P) soils are significantly different from all other soil types, but not significantly different from each other, with an intermediate depth. The deepest soils are found in tree islands (TI) and in prairie with *Melaleuca* (P50 and P75). The statistical analyses are included in Appendix H.

One limitation of the soil depth analysis is that the soil depth stations are clustered in a small area of the Lakebelt Region rather than randomly distributed. Figure 15 shows that all of the Everglades Research Group's stations were clustered at the north end of the study area, with two of the stations (DMS-1 and DM-2) located in Dania Muck and the rest of them in Lauderhill Muck. The prairie stations (P) were all located west of the Dade-Broward levee, while the P50 and P75 stations, except for P50-1, were all east of the levee. The differences between the soil depths in the various cover types therefore might reflect local conditions or the type of soil, rather than the cover type in which the depths were measured. Nevertheless, the fact that DMS soils are shallower than any of the other soils is consistent with the belief that this cover type represents *Melaleuca* resurgence in the wake of wildfires. One would expect shallow soils in areas that had been burned.

3.7 Topography

Lake Belt topography is presented in Figure 17, with the areas between contour lines shaded. Two limitations are apparent in this figure. First, there are no data for the area north of Okeechobee Road, and second, the four foot contour is not complete, so the 3'-4' and 4'-5' ranges had to be combined. The contours show a north-south orientation, and elevations show an east-west gradient, with the land gently sloping up from the Florida Turnpike westward toward Krome Avenue. The area west of the Dade-Broward levee is higher than the land to the east of the levee. There is also a depression in the vicinity of the Northwest Wellfield, where the lowest elevations are found (2' or less).

Tables 14 and 14a show the distribution of the different cover types on the four elevation ranges. The same approach was used to relate cover type to elevation as was described above for soil type, namely, to determine what proportion of the variance can be accounted for by the relative size of the different elevation ranges. Dense *Melaleuca* (M) acreage, when regressed against elevation acreage, yielding a very significant ($p < 0.01$) positive slope, with an r^2 value of 0.971, indicating that the amount of dense *Melaleuca* at any particular elevation range is proportional to the acreage of that elevation range.. This can be seen in Table 14a, which shows that 70% of the dense *Melaleuca* occurs at the 3 to 5 foot elevation range, which accounts for 61% of the Lakebelt Region. The same was true for developed areas (D), canals (C), and tree islands (TI), although D was just barely significant ($p = 0.049$; $r^2 = 0.775$).

ML50, however, reveals a significantly disproportionate relationship with elevation, i.e. there is much more ML50 at the 5 to 6 foot elevation range and much less at the 3 to 5 foot range than would be expected based on size alone. This reflects the fact that most of the ML50 (79%) is found west of the Dade Broward Levee, which is at the 5 to 6 foot elevation range, which only accounts for 37% of the Lakebelt Region. Similarly, Lake (L) distribution is skewed toward the lower elevations in the eastern part of the study area; 91% of the lake area is found in the 3 to 5 foot range, even though it accounts for only 61% of the total Lakebelt Region, and 8% is in the 2 to 3 foot range, which only occupies 2% of the region.

3.8 Hydrology

Average, annual groundwater elevations for each of the six wells selected for this study, for the period 1963 to 1992, are presented in Table 15 and shown graphically in Figure 18. Well locations are shown in Figure 7. Regression analysis was performed on the annual mean groundwater elevation data for each well (elevation vs. time; Appendix J). Only three of the six wells yielded significant slopes: G-974, G-975 and G-976. All three slopes were negative, on the order of 1/10 of a foot drop per year. These three wells are the closest to the Northwest Wellfield, so it is tempting to conclude that the negative slopes reflect drawdown by the wellfield. The wellfield, however, did not start pumping until the early 1980's, yet the downward trend in groundwater elevation in these three wells appears to have begun before that time. To test this, the regressions for these three wells were re-computed using only the 1963 - 1980 data (Figure 19). Well G-974 had a highly significant negative slope ($p=0.0028$); Well G-976 had an almost significant negative slope ($p = 0.0508$); and Well G-975's slope was not significantly different from zero. The significance of at least one of the negative slopes in the early years before the wellfield began operating would appear to rule out pumping alone as a cause of the drop in groundwater levels.

A Pearson correlation analysis compared dense *Melaleuca* cover in six of the eight sections used to measure *Melaleuca* expansion rates with groundwater elevations for the corresponding years at the corresponding wells (See Figure 7). No significant correlation was found for any of the six comparisons. Correlation statistics are presented in Appendix J.

Average monthly groundwater elevations were calculated for the six wells for the last twelve years of the study period, i.e. 1980 through 1992 (Table 17). Figure 19 presents the data graphically. The highest groundwater elevations occurred in Well G-1488, followed in order of decreasing water level by G-975, G-972 and G-976. Wells G-970 and G-974 had similar groundwater elevations for most of this period. This pattern suggests an east-west gradient, with higher groundwater elevations in the west and lower elevations in the east.

Ground elevations at five of the six wells were estimated by superimposing Figure 7 (Well Locations) over Figure 17 (Topography). No topographic information is available in the vicinity of Well G-970. When plotted against groundwater elevation (Figure 20), the ground elevation provides an estimate of hydroperiod in the vicinity of the five wells, i.e. the number of consecutive months in which groundwater elevation is equal to, or greater than the ground elevation. The results reveal the following hydroperiods:

	Hydroperiod
Well G-972	1 month (Sept.)
Well G-974	4 months (Aug.-Nov.)
Well G-975	2 months (Sept. - Oct.)
Well G-976	1 month (Oct.)
Well G-1488	8 months (Aug. - Mar.)

These hydroperiods do not exhibit the same east-west gradient evident in the groundwater elevation data. This is because the topography follows the same gradient. Although it is widely believed that the Pennsuco Basin is wetter than areas east of the Dade-Broward levee (McMahon, 1996, pers. comm.), these data do not fully support that assumption. Well G-1488, which is in the Pennsuco Basin, has a markedly longer hydroperiod than any other well, but well G-975, which also is in the basin, appears to have a lower hydroperiod than Well G-974, which is east of the Dade-Broward Levee.

4.0 Discussion

4.1 *Melaleuca* expansion

Melaleuca has expanded exponentially from 1963 to 1992, at which time it occupied nearly 45% of the Lakebelt Region. Most of this expansion occurred at the expense of ML50, given that: a) ML50 decreased by 32,000 acres during the same period that dense *Melaleuca* increased by 21,000 acres, b) Tree Island, the only other cover type that decreased in size during the same period, was a very small component of the study area in terms of acreage (762 acres in 1963), and c) all other cover types increased due to human activity (Lakes and Disturbed) or remained unchanged (Canal). This is to be expected, since ML50 is only a transitional phase in the succession from prairie to dense *Melaleuca*.

When the eight sections selected were examined, it became obvious that *Melaleuca* is not invading uniformly throughout the region. Six of the sections (5-52-40, 22-52-39, 12-53-39, 28-53-39, 5-54-39 and 4-53-39) are already almost completely covered with dense *Melaleuca,* while the remaining two sections (30-52-39 and 29-53-39) had almost no dense *Melaleuca* until 1989. Once *Melaleuca* foci appear in prairie habitat, expansion is very rapid. The time required for *Melaleuca* to completely overcome a square mile section once the first foci appear is approximately twenty years. Our results agree with Laroche & Ferriter's (1992) conclusion that it takes 25 years to go from 2-5% cover to 95% cover.

The appearance of *Melaleuca* appears to have been delayed by 15 to 20 years in some sections, namely, Sections 05-54-39, 30-52-39 and 29-53-39 (Fig. 13) for reasons that could not be determined. The only factor these sections appear to have in common is that they are all west of the Dade-Broward levee. Once the infection appeared, however, the rate of expansion was dramatic. In Section 29-53-39, for example, dense *Melaleuca* increased from almost nothing in 1989 to cover more than half the section in a period of only three years. In Section 5-54-39, dense *Melaleuca* increased from 18% to 97% during the same three year period.

The sigmoid growth curve reported for this region by Laroche and Ferriter (1992) was clearly evident in only one of the eight sections examined, Section 12-53-39. The other sections that had attained 80% or more cover by 1992 (5-52-40, 22-52-39, 4-53-39, 28-53-39 and 5-54-39) showed no sign of the decreased expansion rate at the upper end of the curve. They appear to have gone through an exponential increase in the early years and then proceeded straight to ±90% cover.

4.2 Soil-cover type relationships

The amount of any given cover type on the various soil types was shown to be a function of the relative amount of that soil type in the Lakebelt Region, suggesting a random distribution with no particular relationship between soil type and cover type.

Soil depths show significant differences that may be related to cover type (Figure 16), but the meaning of these differences is unclear. If soil depth and *Melaleuca* cover were related, one would expect P50 and P75 to have an intermediate soil depth, somewhere between that of prairie (P) and dense *Melaleuca* (DM), because they are transitional stages in the succession from prairie to dense *Melaleuca*, Yet the soil depths in P50 and P75 were significantly greater than those in either prairie or dense *Melaleuca*, and there was no significant difference between soil depths in prairie and dense *Melaleuca*.

4.3 Topography-cover type relationships

No correlation was found between topography and the distribution of *Melaleuca*; the acreage of *Melaleuca* at any given elevation is proportional to the acreage of the Lakebelt Region at that elevation. ML50 shows a disproportionate presence on the higher elevations (5'-6') and D and L show a disproportionate presence at the lower elevations (3'-5'), but these most likely are due to the fact that topography exhibits an east-west gradient, so what appears to be a topographic correlation may simply be a geographic function (i.e. distance from the urban fringe).

4.4 Hydrology-cover type correlation

Melaleuca increased in extent in all six of the sections represented by the six wells during the period 1963-1992. There was no signficant change in groundwater elevation in three of the wells, and a significant decrease in groundwater elevation in the other three over this same period of time. No significant correlation could be found between *Melaleuca* expansion and groundwater level.

The section with the greatest hydroperiod (29-53-39), an eight month hydroperiod indicated by the corresponding well (G-1488), was the last section to experience serious invasion by *Melaleuca*. It was not until 1992 that this section had more than 1% cover of dense *Melaleuca*. Inundation alone cannot explain this phenomenon, however, because the section with the next longest hydroperiod (12-53-39), with a four month hydroperiod indicated by the corresponding well (G-974), had over 50% dense *Melaleuca* cover by

1976, sixteen years earlier. Three drier sections (28-53-39, 30-52-39 and 22-52-39) had only 21%, 6%, and 19% dense *Melaleuca* in 1976, respectively. This is further evidence that the *Melaleuca* invasion rate is not affected by inundation.

4.5 East-West Progression

Another way to examine the data is to rank the eight sections by the year they first attained 50% cover by dense *Melaleuca:*

Rank	Section	Year 50% cover attained	Miles from Fla. Turnpike to Center of Section
1	Section 12-53-39	1976	0.5
2	Section 05-52-40	1984	0.5
3	Section 04-53-39	1989	3.5
T	Section 22-52-39	1992	2.5
T	Section 28-53-39	1992	3.5
T	Section 29-53-39	1992	4.5
T	Section 05-54-39	1992	4.5
8	Section 30-52-39	Not attained as of 1992	5.5

T indicates ties.

This ranking suggests an east-west gradient in certain portions of the Lakebelt. The two sections ranked highest (1 and 2) are adjacent to the Florida Turnpike on the eastern edge of the study area. The third-ranked section and the following four ties are in the central region of the Lakebelt, and the last-ranked section is adjacent to Krome Avenue on the western edge of the study area.

The presence of an east-west gradient in the timing of *Melaleuca* invasion suggests that the existence of a seed source in adjacent areas may be the dominant factor affecting the spread of this species. It is also consistent with a downwind progression, which would be expected for a wind-dispersed seed, since the prevailing winds are from the southeast. Statistical analyses were not performed relating *Melaleuca* expansion to direct physical disturbance of the land surface, such as mowing and/or grazing. Similarly, indirect physical disturbance, such as would be caused by construction, changing the way a canal is operated, and drainage, also was not considered.

5.0 Conclusion

Dense stands of *Melaleuca* presently occupy 44% of the Lakebelt Region. In portions of the Lakebelt Region, *Melaleuca* is apparently spreading rapidly in a westerly direction. No correlations were found between *Melaleuca* growth rate and topography, soil type or hydroperiod. Our data show that there may be an affinity for shallow soils, but a cause-effect relationship cannot be drawn from these limited data. Wildfires slow down its progress for a short time, but *Melaleuca* returns within a few years as dense stands of saplings which will inevitably become dense *Melaleuca* forest.

6.0 Recommendations for Future Study

This study was somewhat limited in scope because of budgetary constraints. Photointerpretation, digitization and GIS analysis are very labor-intensive and expensive. Our analysis focused on the mapping and inventory aspects of the Lakebelt Study, with limited statistical analysis. All of the raw data, however, are presented in the appendices so that others can continue to analyze the data using more sophisticated techniques. More thorough analysis of the same data, using more sophisticated analyses, might provide additional insight into the factors that determine how *Melaleuca* is dispersed and how fast it spreads.

The analysis presented in this report should be updated periodically using more recent aerial photography. Analysis of the 1996 aerials now available would add another point to each of the graphs of *Melaleuca* expansion, and would help clarify the shapes of the curves.

We also recommend that future studies divide the Lakebelt into subregions. Based on the results of this study, the Lakebelt Study Area appears to consist of a series of distinctive subregions with different physical characteristics and vegetative associations. Regional analysis might be more useful from a planning point of view than the regionwide approach used in this study.

Acknowledgements

We would like to express our gratitude to Dr. Steven Green of the University of Miami for his assistance with the statistical analyses and to Mr. Scott Prinos of the U.S. Geological Survey for providing the wellfied data summaries.

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